AFCRL-65-673

Ionospheric Research

Contract No. AF19(628)-4050

Scientific Report

on

Rocket Instrumentation for the Measurement of D-Region Electron Density and Collision Frequencies

by

T. A. Seliga, D. J. Hoffman and J. S. Nisbet

July 1, 1965

Scientific Report No. 244

"The research reported in this document has been sponsored by the Defense Atomic Support Agency, Washington, D.C. under Subtask 07.530, and in part, by the National Aeronautics and Space Administration under Grant NsG-134-61."

Ionosphere Research Laboratory

Submitted by: J. S. Nisbet (aw)

J. S. Nisbet, Associate Professor
of Electrical Engineering
Project Supervisor

Approved by: A. H. Waynick

A. H. Waynick, Professor of
Electrical Engineering, Director
Ionosphere Research Laboratory

The Pennsylvania State University
College of Engineering
Department of Electrical Engineering

Prepared for

Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

ABSTRACT

This report describes the instrumentation designed to be flown in a Black Brant II rocket, AC17.606. Three experiments are included in the design and are 1.) an AC conductivity probe, 2.) a low frequency propagation experiment and 3.) a temperature probe.

TABLE OF CONTENTS

1.0 Introduction

This experiment was designed to study some of the little understood factors in D-region rocket experiments. Three main topics were considered, the effect of the boundary layer, the effect of the Mach cone and the effect of the ion sheath.

To study effects of the boundary layer, two probe configurations were included. The first consisted of an arrangement of steel balls separated from the nosecone skin by 1.62 inches. Also included were pairs of parallel plates mounted flush with the nosecone surface. Balls and plates were connected to identical bridge circuits for measuring the resistive and capacitive components of the impedance at 100 and 512 kc/s. The balls were calculated to be far enough from the nosecone surface to be outside the boundary layer while the parallel plates were within the boundary layer. During ascent the balls would be continuously inside the nosecone Mach cone but on descent it was expected that the rotation of the rocket and the re-entry attitude would be such that they would be outside this cone.

The effect of the plasma sheath was to be studied by making measurements on both configurations while solidly grounded to the main rocket body. Two additional gauges designed to measure the electron and positive ion temperatures and the vehicle potential were included.

In addition to the probes a propagation experiment was designed to provide data on the low frequency propagation constants of the ionosphere for comparison with the local measurements.

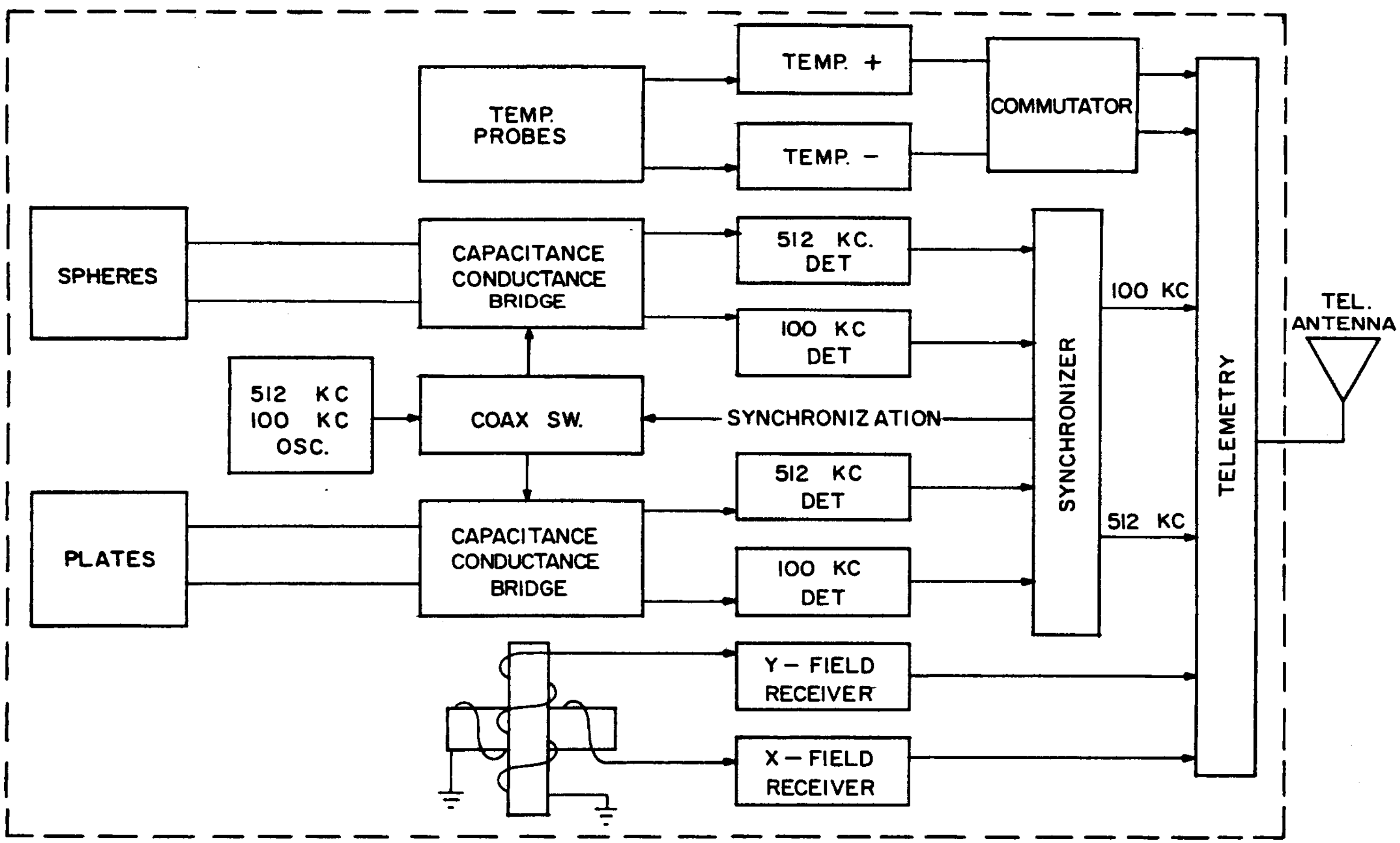
A block diagram of the system designed to perform the experiments is shown in Figure 1. A slightly different version of the conductivity probe and propagation experiments was flown successfully on two Black Brant II rockets in July of 1963. Seliga and Vogt (1963) described the instrumentation for those flights. Consequently, only the differences in instrumentation between this experiment and that described by Seliga and Vogt are covered in this report.

2.0 Conductivity Probe Experiment

The AC conductivity experiment was designed to measure the conductance and capacitance alternately between sets of plates and spheres. Figure 2 is a photograph of the probes as they were mounted to the rocket nosecone while Figure 3 illustrates the details of the spherical probes. The exact dimensions of the probes which were designed for AC 17.606 are given in Figure 4.

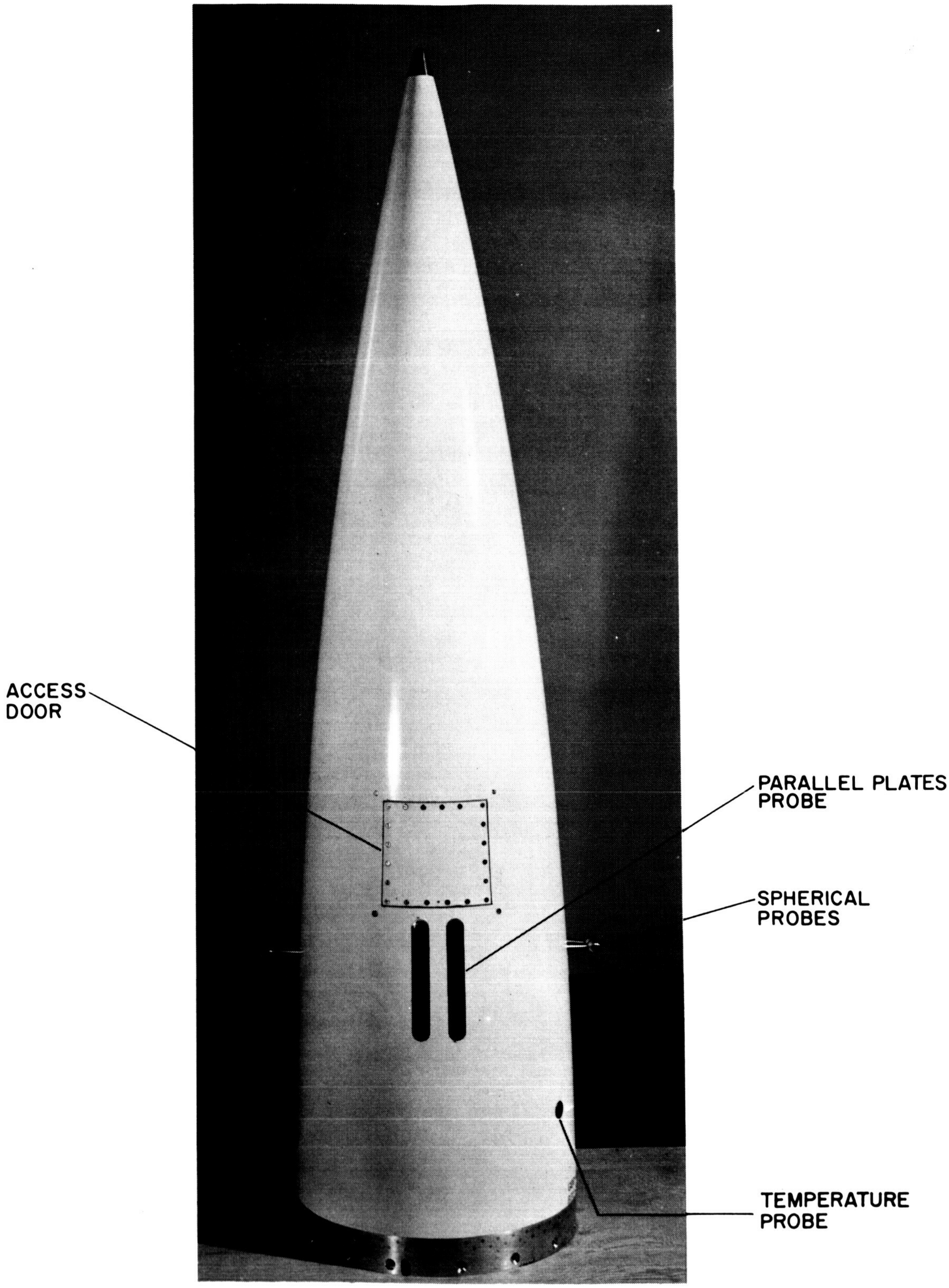
Both probes were made of stainless steel. The plates were made of 1/8" stock and set in flush to the skin of the nosecone. The spheres are a nominal 1" diameter and are mounted on conical sections whose sides are kept parallel as shown in Figure 3. The two probe configurations were designed to determine any differences between a probe mounted flush to the skin and one extending a short distance from the skin.

Figure 5 shows the internal electrical connections and locations of the probes. Two pairs of each probe were used in order to produce a configuration which is symmetrical about the nosecone.



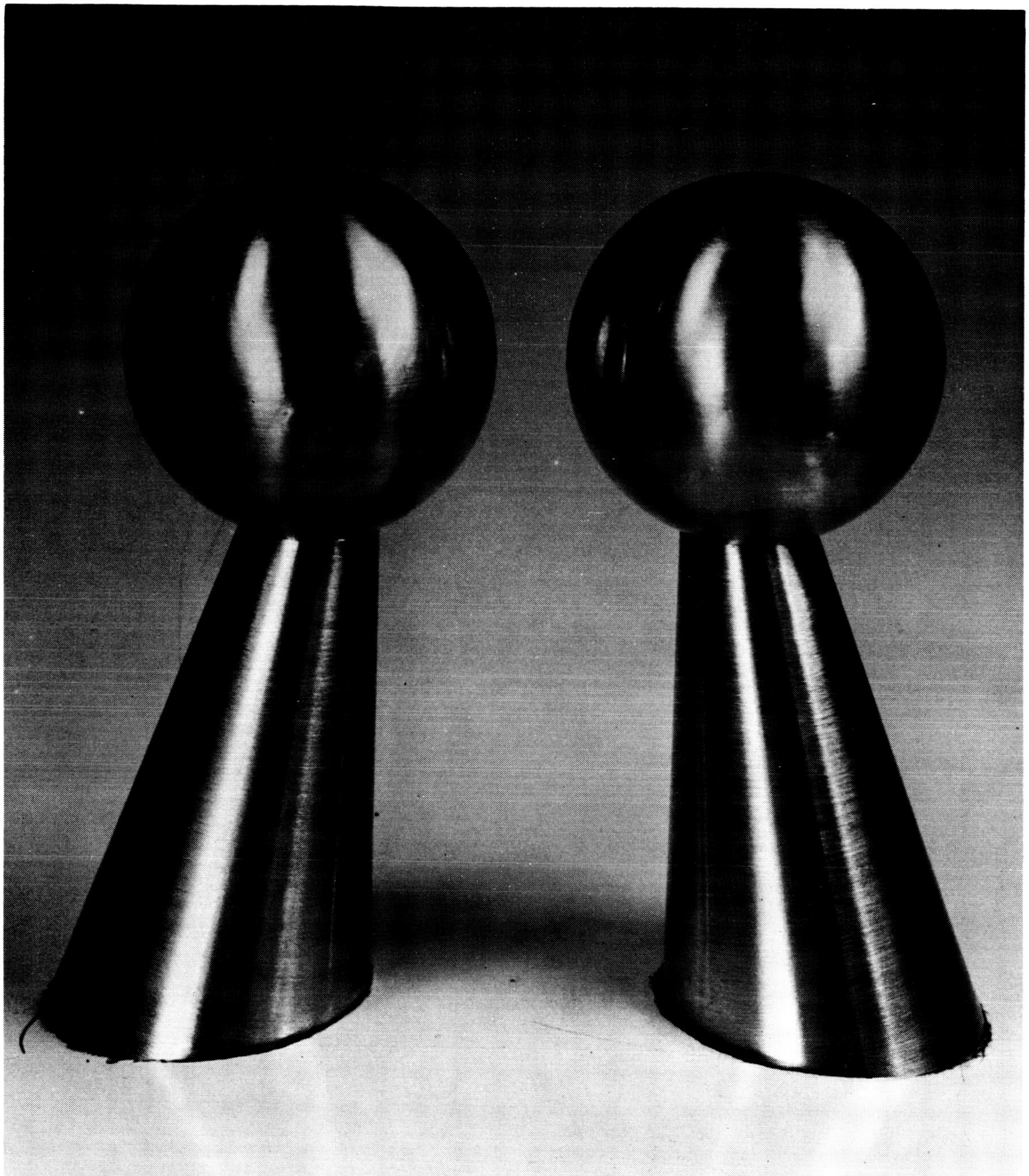
PENN STATE ROCKET BORNE INSTRUMENTATION FOR
BLACKBRANT II A (AC17-606)
FUNCTIONAL BLOCK DIAGRAM

FIGURE I



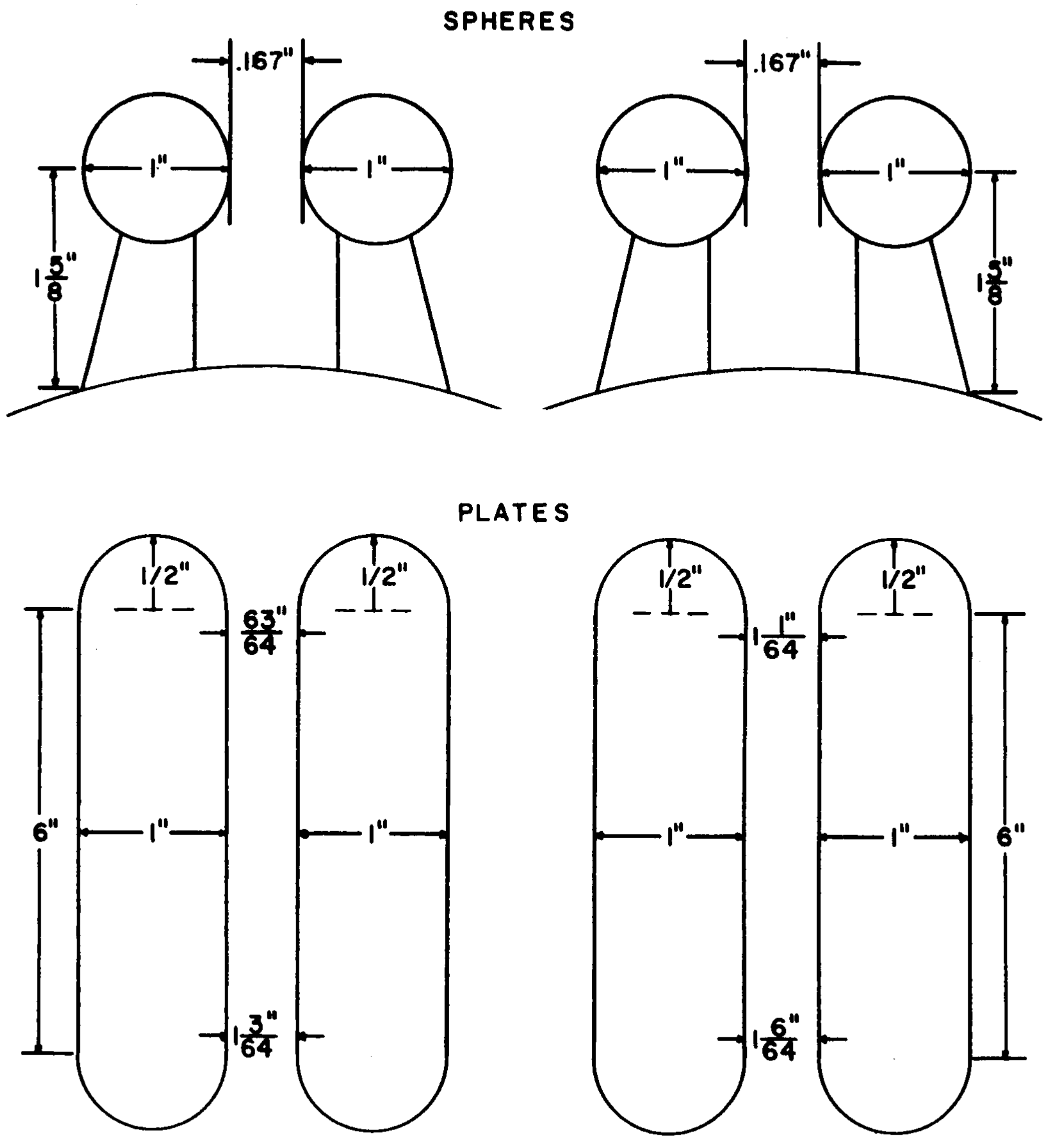
NOSECONE AND EXTERNAL PROBE CONFIGURATION

FIGURE 2



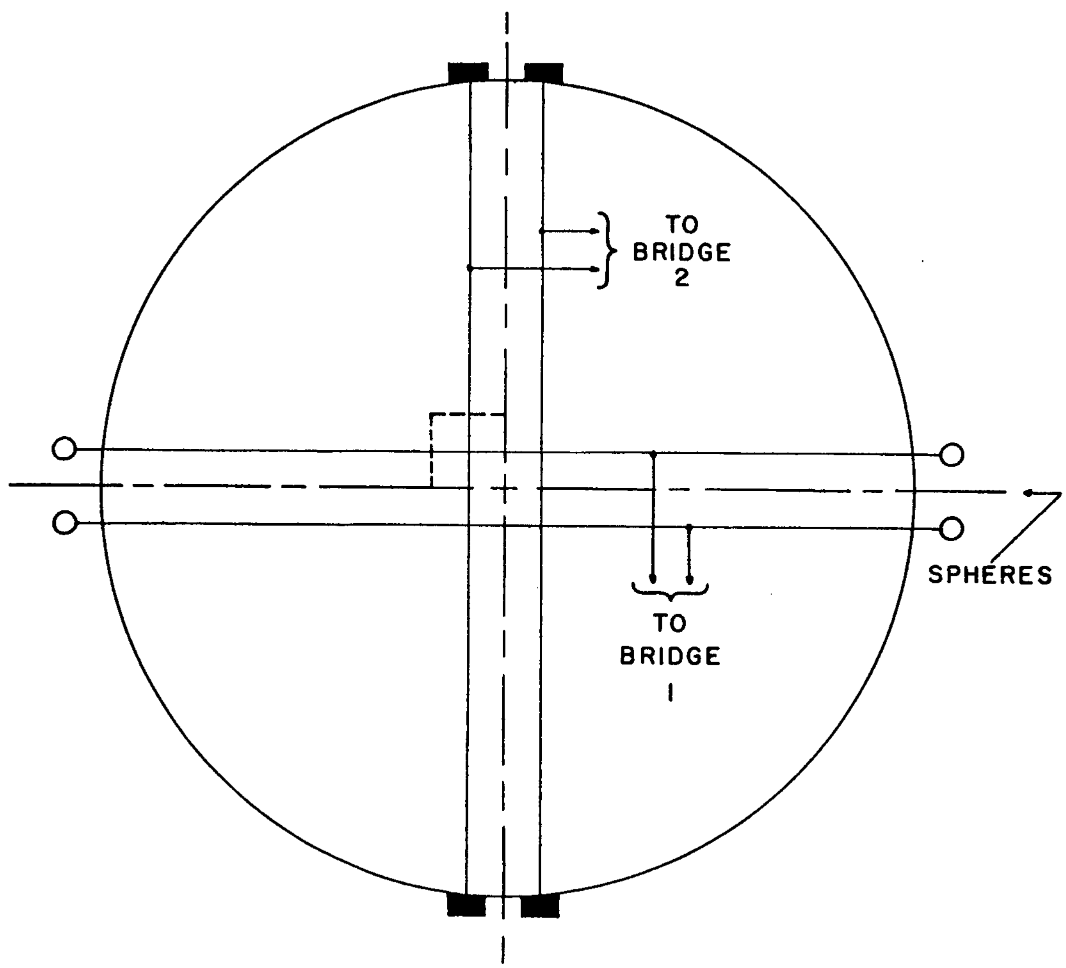
CLOSEUP VIEW OF SPHERICAL PROBES

FIGURE 3



PROBE DIMENSIONS

FIGURE 4



CROSS-SECTION OF NOSE CONE

INTERNAL ELECTRICAL CONNECTIONS
AND EXTERNAL PROBE CONNECTIONS

FIGURE 5

2.1 Probe Instrumentation

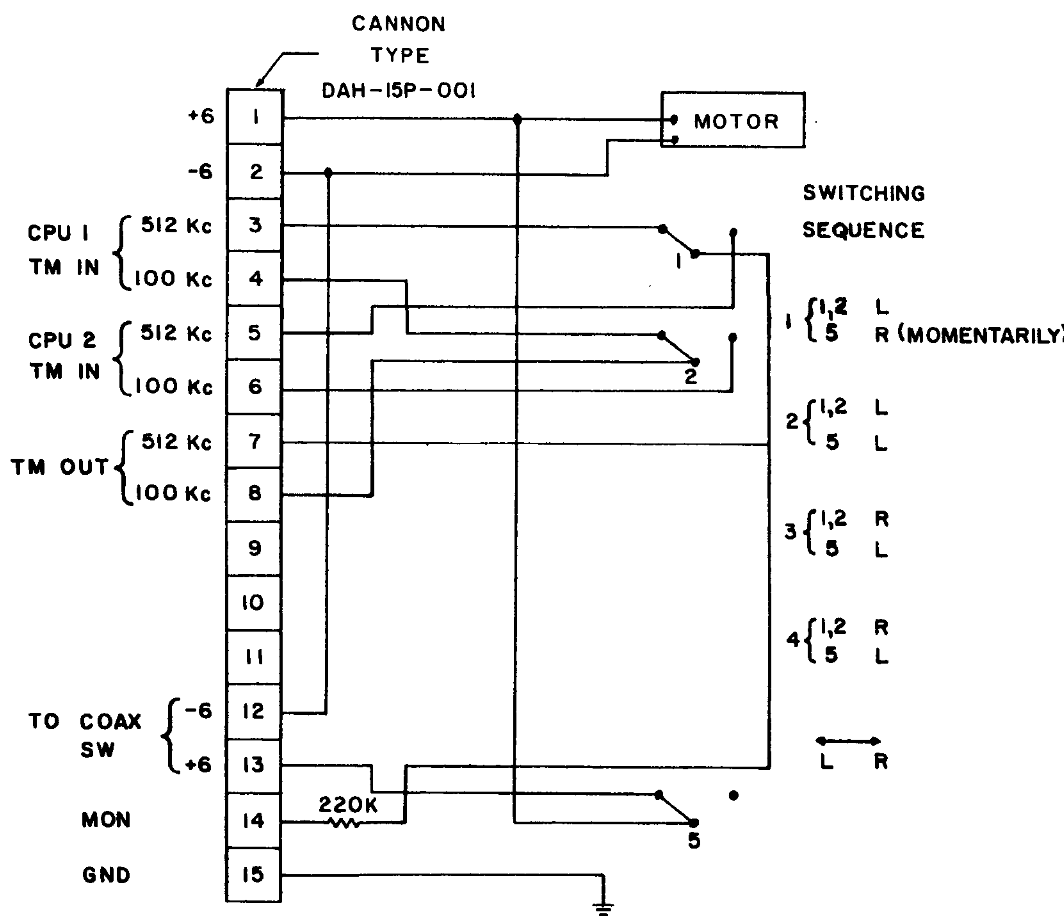
The impedance across the probes is measured with a capacitance conductance bridge circuit. The bridge is fed by a dual source (512 kc/s and 100 kc/s) oscillator so that impedance measurements could be made simultaneously at both frequencies. The detectors consisted of tuned RF amplifier stages having a logarithmic detection characteristic which served as the telemetry input. The oscillator, bridge, and detector are described thoroughly by Seliga and Vogt (1963). The only difference is that a coaxial switch has been added so that the two probe units can time share the oscillator output.

2.2 Synchronizer

Because of a limited number of available telemetry channels, the outputs from the detectors were time shared between the two probe configurations. The synchronizer is made up of cam actuated micro-switches, and the cam is driven by a 12 volt DC motor. The operation of the snychronizer is such that during the first half cycle the signals from the spherical detectors are fed to telemetry, while during the second half cycle the telemetry inputs are derived from the plate detectors. The circuit diagram of the synchronizer is given in Figure 6. The synchronizer also controls the coaxial switch which synchronizes the output of the oscillator with the proper probe unit.

3.0 Propagation Experiment

The instrumentation for the propagation experiment is described by Seliga and Vogt (1963). Only the antenna structure has been changed for this payload.



SYNCHRONIZER SCHEMATIC DIAGRAM

FIGURE 6

3.1 Low Frequency Receiving Antennas

Two ferrite loop antennas made up part of the payload and were used to receive a low-frequency CW wave which was transmitted from the ground to the rocket. One antenna was oriented along the rocket axis while the other was aligned perpendicular to the rocket axis. The antennas were mounted on a deck above the receivers as far away as possible from the rest of the instrumentation in order to reduce pickup and possible feedback.

Each antenna consisted of four ferrite blocks around which was wound 50 turns of No. 16 enameled copper wire. The wire was wound in two layers of 25 turns each. The antenna was set into a piece of Micarda tubing whose ends were sealed with machined pieces of Synthane.* Prior to sealing the antenna, leads were mated to a coaxial cable which was fed through a hole in the Micarda tubing. The remaining space in the tube was filled with foam (Eccofoam F2) in order to insure rigidity and provide shock protection to the antennas.

The antennas were measured to have a Q of approximately 30. Tuning was accomplished with variable capacitors which were mounted in separate aluminum boxes near the antennas. The equivalent length of each antenna was approximately 0.3 meters. The antennas were connected to their respective receivers by coaxial cables which mated to the tuning boxes.

4.0 Temperature Probes

The electron and positive ion temperature units were identical except for the bias polarity to the metallic conductors which were

*Manufactured by Snythane Corporation, Oaks, Pa.

mounted flush to the nosecone surface. These circular metallic plates were 1" in diameter and one of them may be seen in Figure 2. In the ionosphere these conductors exhibit a diode type characteristic and relations between the current, voltage and particle temperature can be derived.

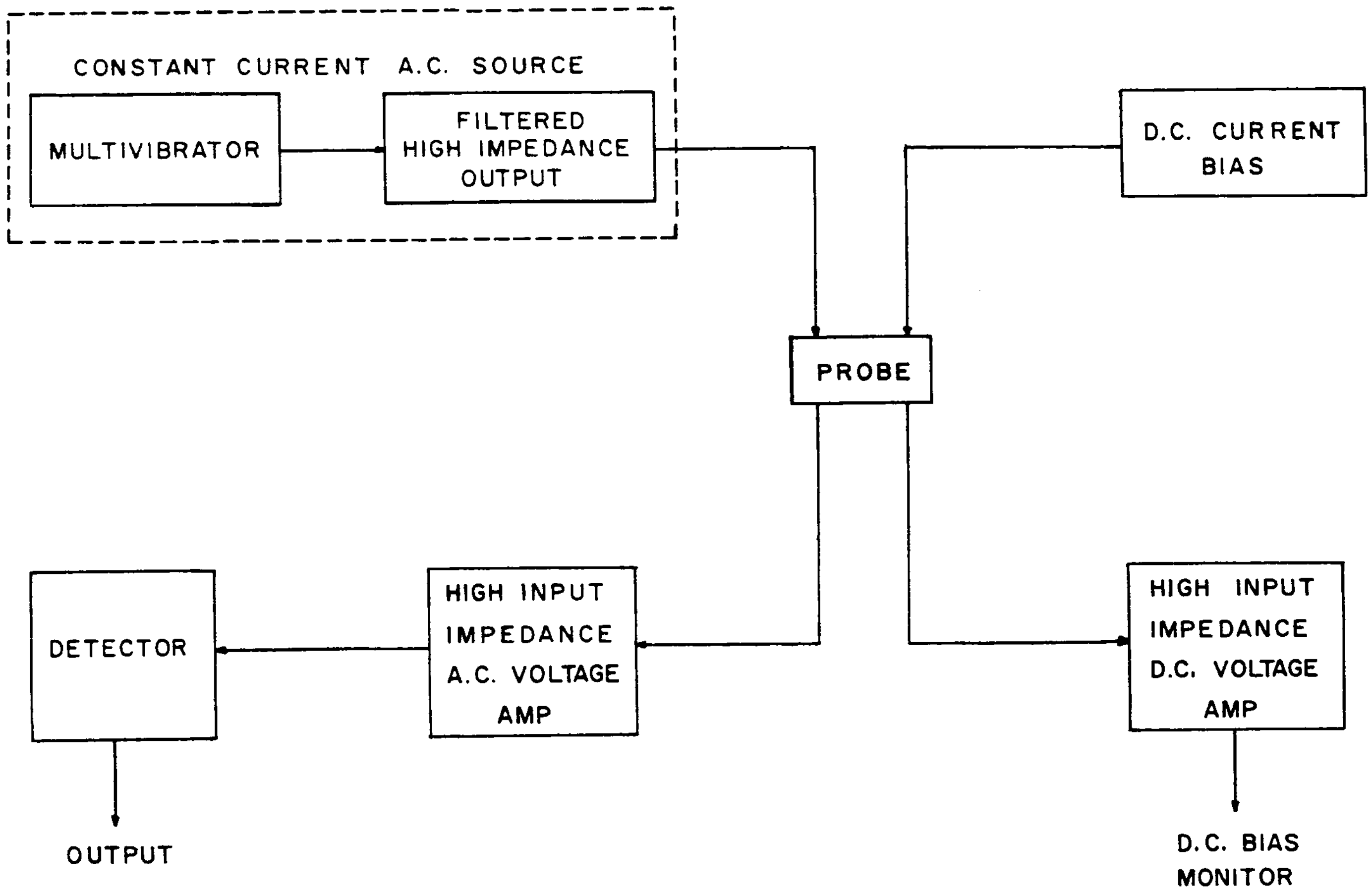
By keeping a constant DC current and applying a small constant AC current to the probe, and detecting the AC voltage across the probe, it is possible to obtain a measurement of the temperature of the current carriers. The electron probe has a positive bias to attract electrons and the ion probe has a negative bias to attract the positive ions in the ionosphere.

Figure 7 is a block diagram of the temperature unit. The constant current AC source is a multivibrator with a filtered, high impedance output. The DC bias level to the probe is detected by a high impedance amplifier using a field effect transistor. The AC signal is amplified and detected by a simple diode detector. The output of the detector is approximately 0 to 1.5 volts over a range from 10 kΩ to several megohms probe impedance. The schematic diagram for one of the units is shown in Figure 8. Figure 9 illustrates the AC resistance characteristics of the probes.

5.0 DC-DC Converter and Battery Supply

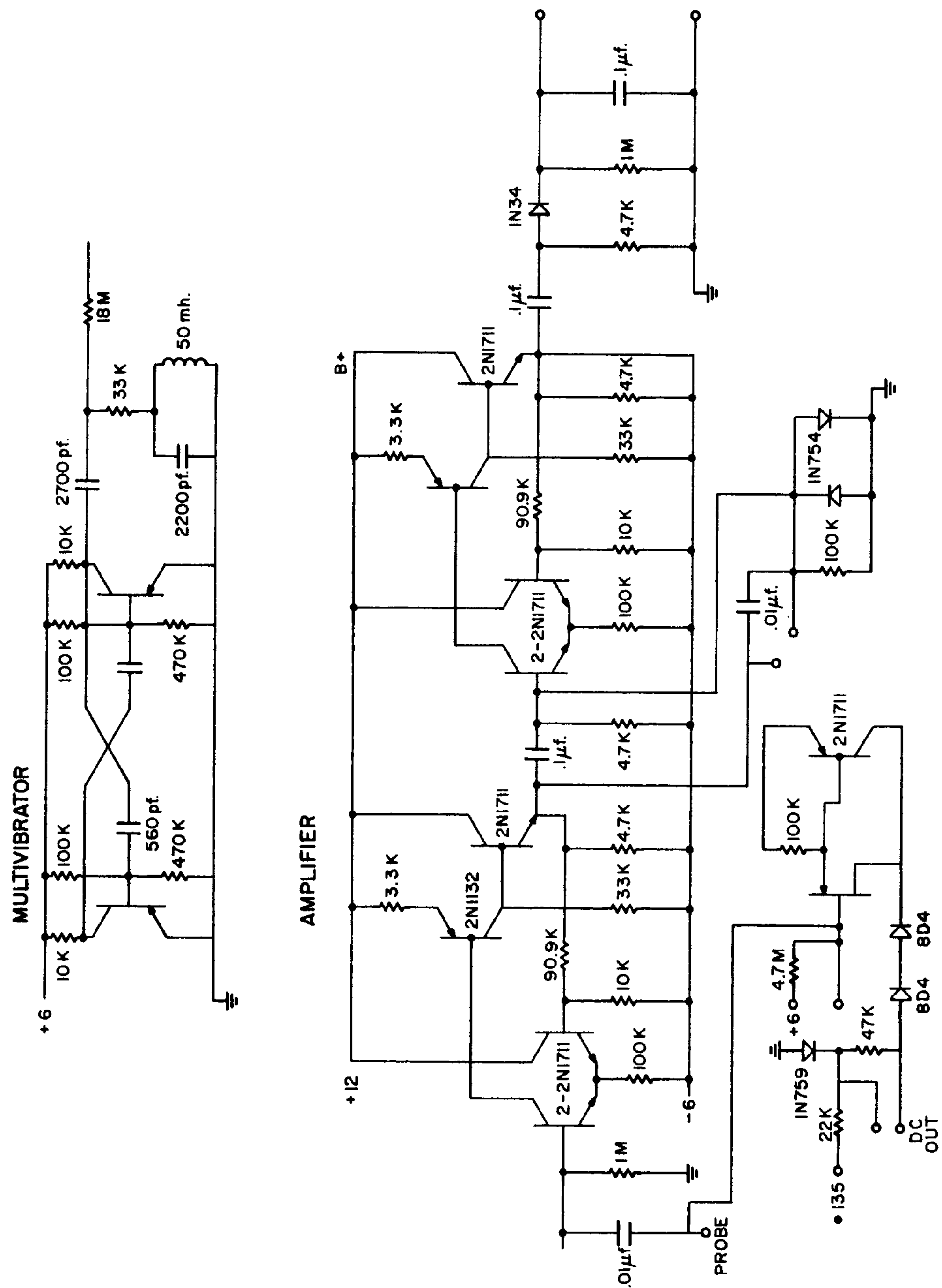
The converter was in a common emitter configuration and was a modification of the TY-81 model made by Triad Transformer Corporation. The converter supplies B+, 135 volts, from the 12 volt battery pack. Its schematic diagram is shown in Figure 10.

The basic power supply was eight PM-5 Yardley Silvercels



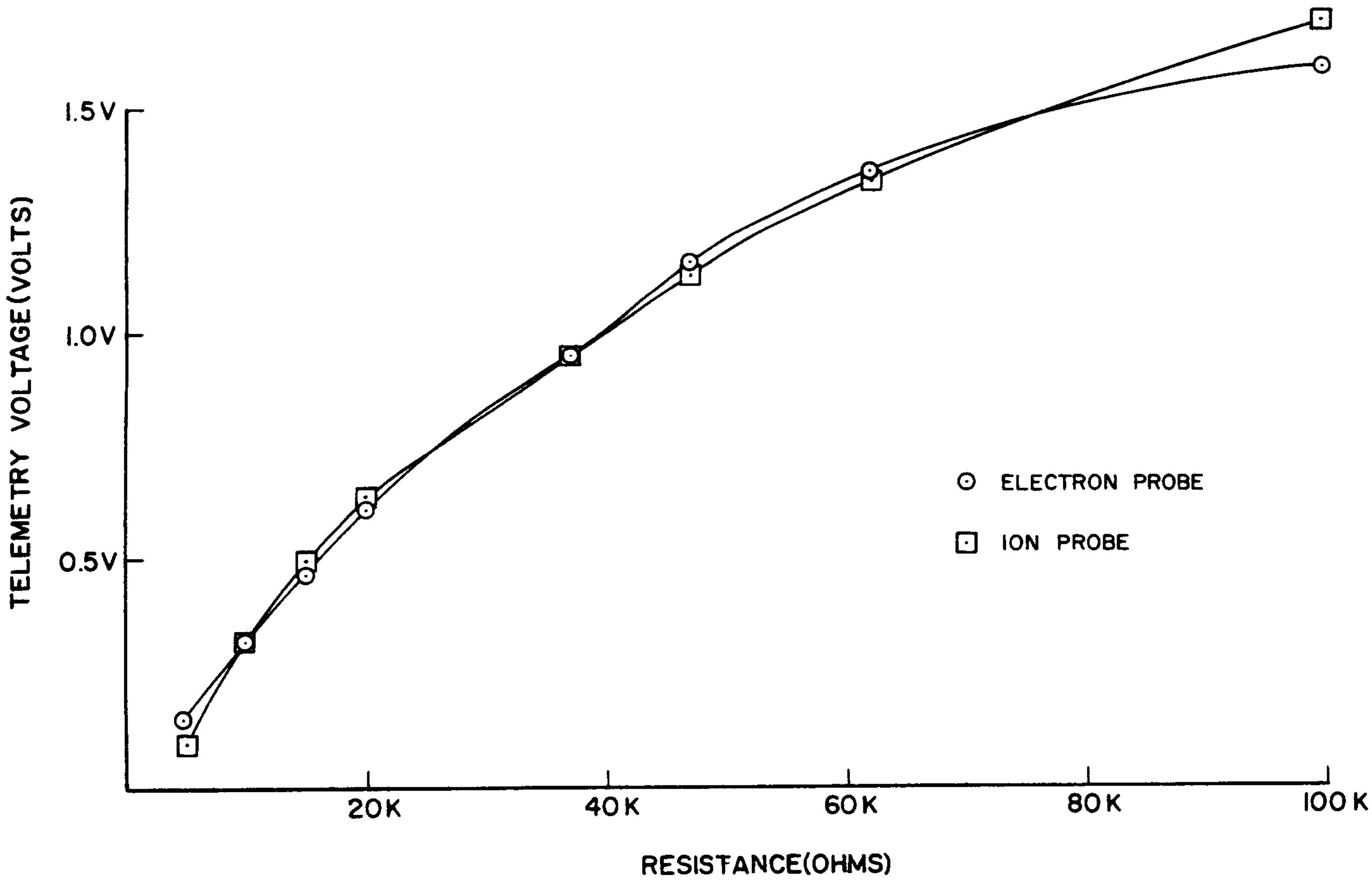
BLOCK DIAGRAM OF TEMPERATURE UNIT

FIGURE 7



TEMPERATURE PROBE ELECTRONICS

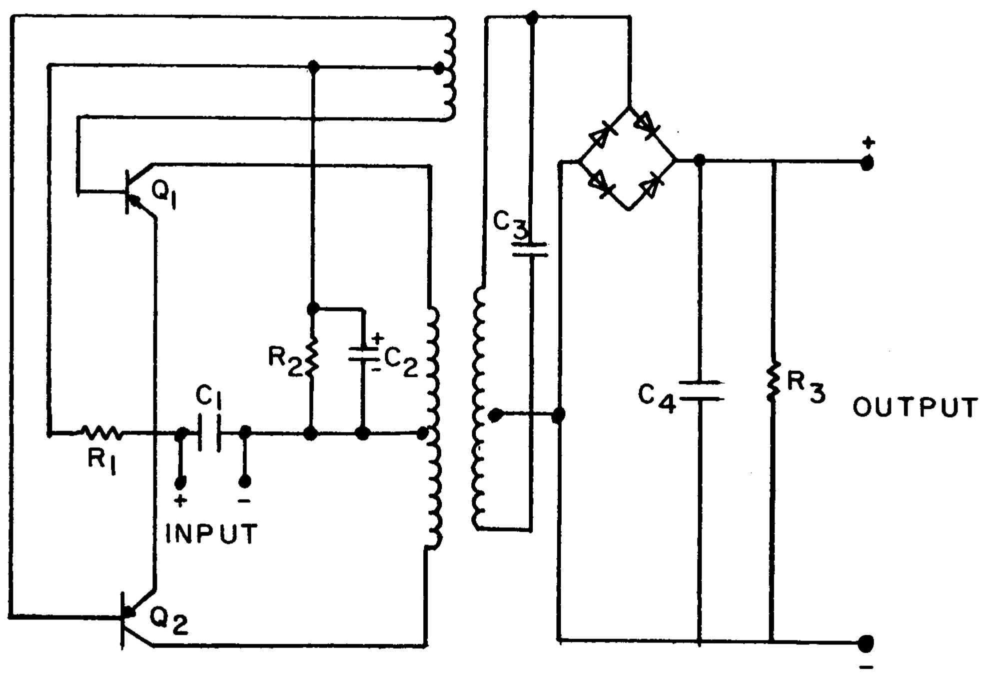
FIGURE 8



TEMPERATURE PROBE CALIBRATION CURVE

FIGURE 9

POWER REQUIREMENTS:
12 VOLTS DC INPUT
150–170 VOLTS DC OUTPUT @ 0.2 AMPS
OUTPUT POWER – 170 X 0.2 = 34 WATTS



R_3 = 30 K/10 WATTS
C_1 = 250 μf/25 VOLTS
C_4 = 5 μf/450 VOLTS
R_1, R_2, C_2 – OPTIMUM STARTING AND BASE DRIVE
C_3 – MINIMUM SPIKES ON COLLECTOR AND EMITTER WAVEFORM

DC–DC CONVERTER

FIGURE 10

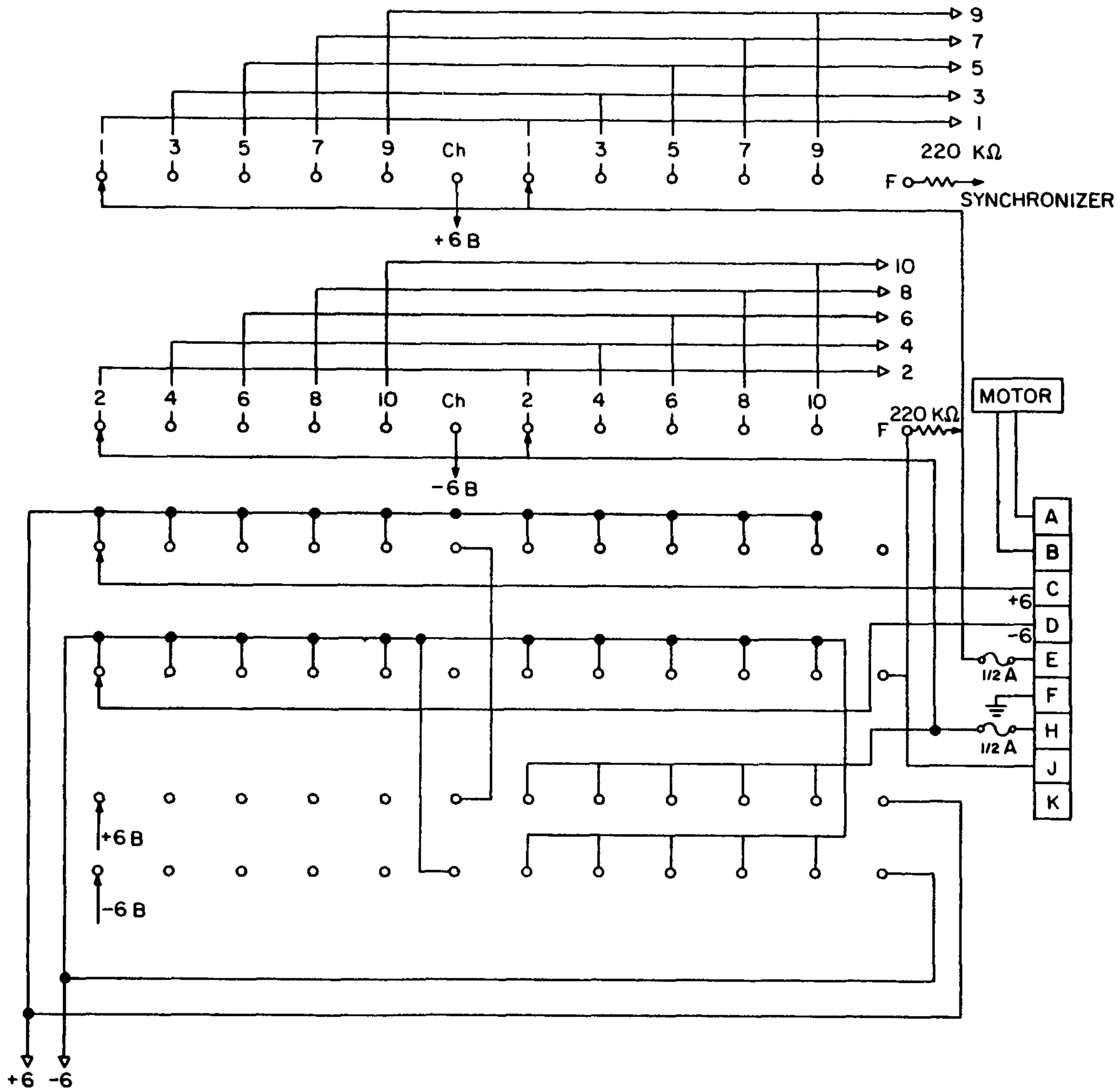
connected in series. The output of the Silvercels provided all the power to the instrumentation and was distributed through the control box. A circuit diagram of the control box is given in Figure 11.

6.0 Remote Control Unit

The functions of the remote control unit are described by Seliga and Vogt (1963). However, the unit was modified and its schematic is given in Figure 12. The modifications included the addition of a scheme to monitor all the telemetry inputs in the block-house while operating under both internal and external power. Also requiring alteration was the DC supply voltage to the stepping switch in the Control Box from 110 to 28 volts.

References

Seliga, T. A. and R. W. Vogt, Rocket Instrumentation for the Measurement of AC Conductivity, with a Capacitive Probe, and Long Wave Propagation in the Lower Ionosphere, Ionosphere Research Laboratory, Pennsylvania State University, Sci. Report (E) No. 181.

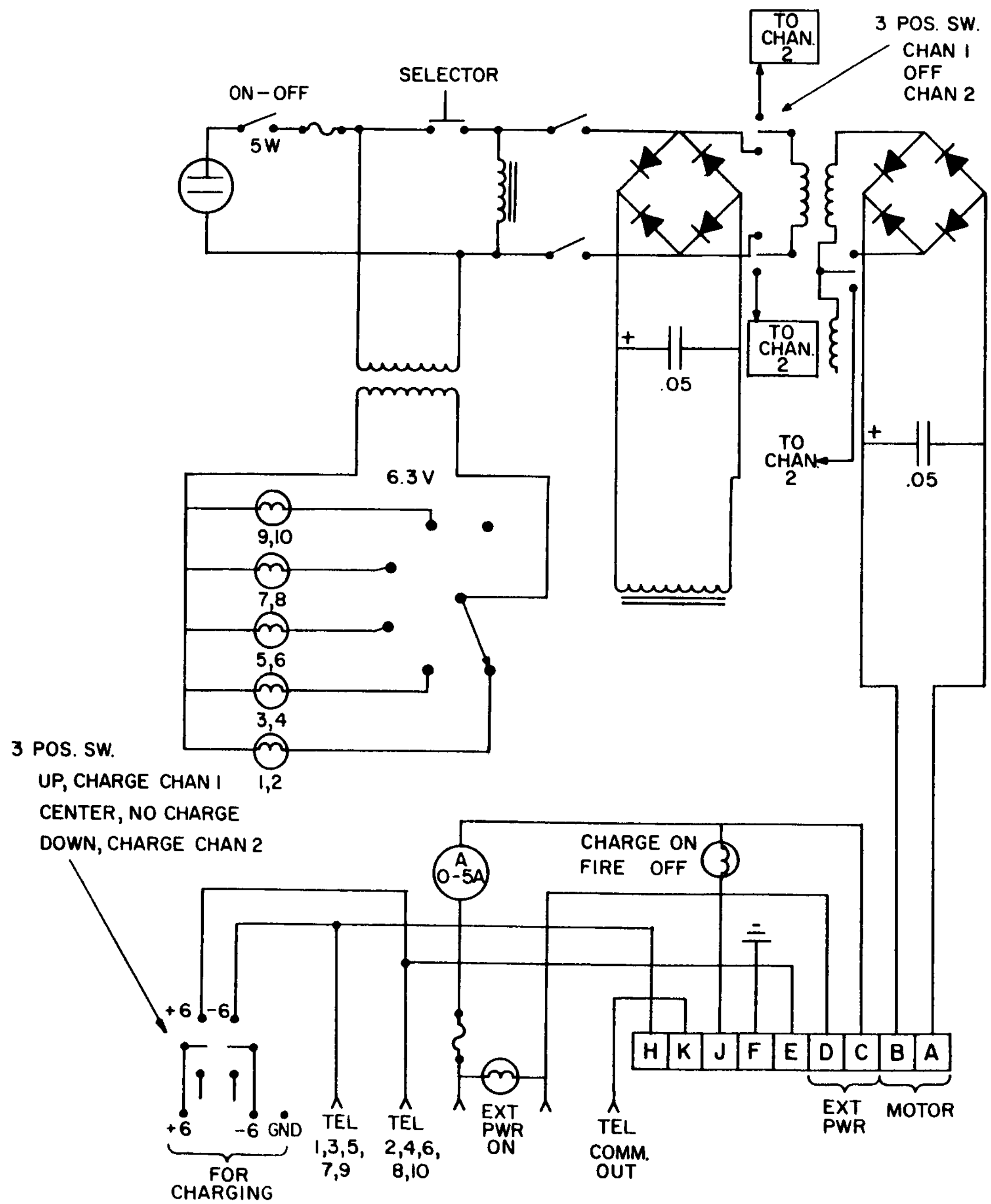


1 - CPU NO.1 (512 kc/s)
2 - CPU NO.1 (100 kc/s)
3 - CPU NO.2 (512 kc/s)
4 - CPU NO.2 (100 kc/s)
5 - 163 kc/s RCVR (X-ANT.)
6 - 163 kc/s RCVR (Y-ANT.)
7 - ELECTRON ION
8 - ELECTRON ION
9 - ELECTRON ION
10 - ELECTRON ION
12 - FIRE (MON. COMMUTATOR OUTPUT)

(CPU - CAPACITANCE PROBE UNIT)

CONTROL BOX

FIGURE 11



REMOTE CONTROL UNIT CIRCUIT DIAGRAM

FIGURE 12

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* The Ionosphere Research Laboratory, The Pennsylvania State University, University Park, Pennsylvania	2a. REPORT SECURITY CLASSIFICATION Unclassified; 2b. GROUP
3. REPORT TITLE Rocket Instrumentation for the Measurement of D-Region Electron Density and Collision Frequencies	
4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)* Scientific Report No. 244	
5. AUTHOR(S) *(Last name, first name, initial)* Seliga, T. A., Hoffman, D. J., Nisbet, J. S.	
6. REPORT DATE July 1, 1965	7a. TOTAL NO. OF PAGES 18; 7b. NO. OF REFS 1
8a. CONTRACT OR GRANT NO. AF19(628)-4050	9a. ORIGINATOR'S REPORT NUMBER(S) Scientific Report No. 244
b. PROJECT NO.	
c. TASK	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)* AFCRL-65-673
d.	
10. AVAILABILITY/LIMITATION NOTICES Qualified requestors may obtain copies of this report from DDC. Other persons or organizations should apply to the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Sills Building, 5285 Port Royal Road, Springfield, Virginia 22151.	
11. SUPPLEMENTARY NOTES Prepared for: AFCRL, OAR, USAF (CRU), Bedford, Massachusetts	12. SPONSORING MILITARY ACTIVITY Defense Atomic Support Agency Washington, D. C.

13. ABSTRACT

This report describes the instrumentation designed to be flown in a Black Brant II rocket, AC17.606. Three experiments are included in the design and are 1.) an AC conductivity probe, 2.) a low frequency propagation experiment and, 3.) a temperature probe.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
AC conductivity probe, a low frequency propagation experiment and a temperature probe.						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, *or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.